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Palynofacies analysis and paleoenvironmental reconstruction of Umuna well, Anambra basin, South Eastern Nigeria.

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ABSTRACT

Depositional environment of thirty-one (31) ditch cuttings from Umuna well were determined using particulate organic matter generated from the ditch cuttings. Umuna well is located in Imo State, within the Anambra basin, South-eastern Nigeria. The ditch cuttings ranged in depth from 1010ft at the top to 2890ft at the base and were prepared into palynological slides following the non-acid sodium hexametaphosphate (NaPO3)6 method for deflocculation of samples, and wet sieved through 10µ diameter sieve. The palynological slide generated were analysed and the different particulate organic matter differentiated based on their grain boundary (Sharp, irregular or diffuse), shape (equidimensional or bladed), colour (opaque or translucent). The analysis yielded percentage distributions of the particulate organic matter components which included the phytoclast, amorphous organic matter and palynomorphs. The results were presented in charts and plotted out in a ternary diagram. The percentage distributions of the phytoclast, amorphous organic matter and palynomorphs plotted in seven depositional environments labelled (I, II, III, IVb, V, VI and IX) within marginal marine to shallow marine. The marginal marine depositional environments predominate in the studied section and included, highly proximal shelf (I), marginal dysoxic-anoxic basin (II) and heterolithic oxic shelf (III), while the shallow marine depositional environments included shelf to basin transition (IVb), mud-dominated oxic shelf (V), proximal suboxic-anoxic shelf (VI) and proximal suboxic-anoxic basin (IX).

Key words: paleoenvironment, particulate organic matter, Palynofacies, phytoclasts, palynomorphs.

INTRODUCTION

The term *palynofacies* was first used by [1] as a component of Organic Petrology, to further explain Palynology and Coal Petrology. Palynofacies was defined by [2] as a "distinctive assemblage of hydrochloric acid (HCl) and hydrofluoric acid (HF) insoluble particulate organic matter (*palynoclasts*) whose composition reflects a particular sedimentary environment". [1], defined Palynofacies as "the total assemblage of microscopic organic constituents present in a rock that remained after maceration in hydrochloric acid (HCl) for carbonates and by hydrofluoric acid (HF) for silicates, concentration and mounting using normal palynological preparation procedures". [3], introduced a modern concept of palynofacies study in which he defined palynofacies as "a body of sediment containing a distinctive assemblage of palynological organic matter thought to reflect a specific set of environmental conditions or to be associated with a characteristic range of hydrocarbon-generating potential" while he defined palynofacies analysis as: "the palynological study of depositional environments and hydrocarbon source rock potential based upon the total assemblage of particulate organic matter". Palynofacies analysis is used to characterize the type of kerogen with their relative abundance for providing information on the depositional environment and probable area of the hydrocarbon generation of the sediments. This analysis involves the holistic view of palynomorphs and assemblages of particulate organic matter present in the thirty ditch cuttings recovered from Umuna well in Anambra basin, towards interpreting their depositional environment.

General Geology of the region

Umuna well is located in Imo State and lie within longitudes 6°30'34"E and latitudes

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3°48'37"N in the Anambra basin of the south-eastern Nigeria (Fig. 1). The Anambra basin tectonically, originated from the Santonian compressional movement along the NE–SW trend. This resulted in the uplift of the Abakaliki fold belt. This uplift was contemporaneous with the subsidence of the Anambra platform and the displacement of the axis of the basin towards SW of the Benue folded belt and NW of the Abakaliki uplift. This tectonic activity created a depo-centre at the Anambra platform which received sediments from Campanian to Palaeocene [4].

The sedimentary fills of the Anambra basin commenced with deposition of the Campanian-Maastrichtian marine and parallic Nkporo Shale and Enugu Formation. Deposition of sediments of the Enugu/Nkporo Formations were overlain successively by the Mamu, the Ajali, the Nsukka and the Imo Shale respectively. The Nsukka Formation and Imo Shale marked the onset of another transgression in the Paleocene. The Imo Shale contain significant amount of organic matter and may be a potential source for hydrocarbons in the northern part of the Niger delta [5].

Within the last decade many attempts have been made to categorise the microscopic palynofacies components of sediments and relating them to hydrocarbon generation and palaeoenvironmental interpretations by many authors such as; [6]; [7]; [8]; [9]; [10].

MATERIALS AND METHODS

The methods adapted in the study included sampling, description, preparation, analysis and interpretation. Thirty (30) ditch cuttings properly sampled at 60ft intervals from Umuna well were bagged in a clean sample bag to avoid contamination, labelled and transported to the laboratory for description, preparation and analysis.

The sample descriptions included physical examination of the samples to identify their colour, texture and grain sizes from where a lithological log was generated. Hydrochloric acid was used to treat the samples to check for effervescence which is an indication for carbonaceous content.

The thirty ditch cuttings recovered from Umuna well were prepared into a standard palynological slide in the laboratory following the standard non-acid sodium hexa-metaphosphate ($(NaPO_3)_6$) palynological preparation method.

The analysis of the thirty samples prepared involved the integration of all facets of the palynological organic matter recovered in the palynological slide under study. This included scanning distinct components and evaluation of the comparative percentages of the different constituents and their preservation states. The three main groups recovered within the particulate organic matter under the projected light microscope are as follows:

I. Palynomorphs – These are organic walled components that were retained after maceration.
II. Phytoclasts – These are tissues fragments recovered from higher plants or fungi.
III. Amorphous organic matter – These are substances with no definite shape and were recovered from non-fossilizing algae, or a more complex tissue biodegradation, phytoplankton or bacterially recovered organic matter.

The comparative percentages of the varied components recognized in each of the palynological slides prepared from the ditch cuttings was tabulated statistically in percentages, depth by depth. The statistical data generated was called-up into StrataBugs application to generate biostratigraphic charts for palaeoenvironmental interpretation. These biostratigraphic charts showed individual occurrences of the three-main particulate organic matters, where they occur down hole, how they occur and their percentage distribution.

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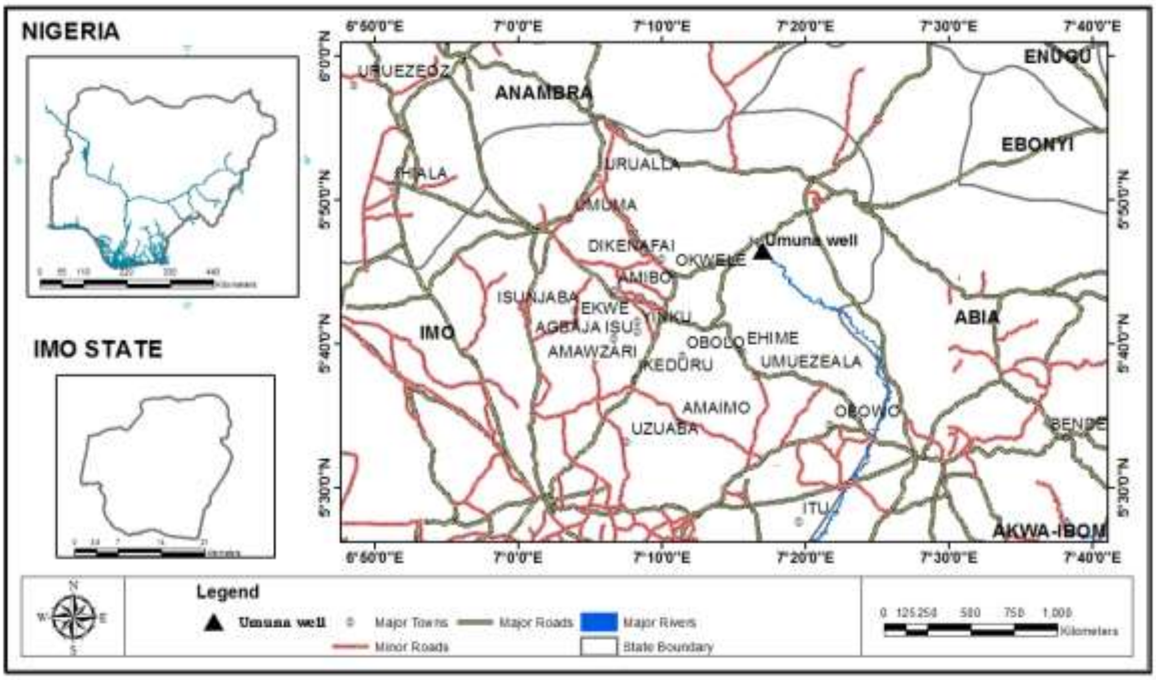

Fig. 1: Location Map of the study area showing the well point and other physical features such as major and minor roads.

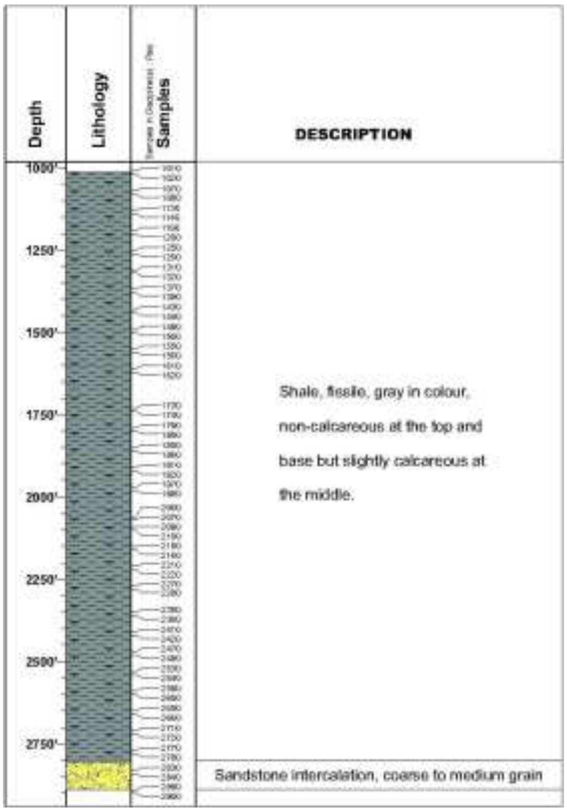

Fig. 2: Lithologic description of Umuna well.

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Table 1: Particulate organic matter components statistical table

Depth (ft)	Opaque Phytoclast	Non-opaque Phytoclast	Palynomorph	Amorphous organic matter
1010	58	7	30	5
1070	47	17	26	10
1130	35	30	24	11
1190	60	10	25	5
1250	27	13	48	12
1310	29	2	67	2
1370	28	23	15	34
1430	46	28	1	25
1490	20	8	63	9
1550	35	5	57	3
1610	27	10	53	10
1730	30	16	30	24
1790	47	20	5	28
1850	34	32	4	30
1910	69	14	7	10
1970	72	18	0	10
2060	68	8	6	18
2090	83	9	1	5
2150	85	3	10	2
2210	79	12	6	3
2270	84	9	0	7
2350	72	7	18	3
2410	40	28	1	31
2470	71	16	8	5
2530	23	5	67	5
2590	63	11	14	12
2650	60	17	5	18
2710	70	18	2	10
2770	36	13	50	1
2830	80	6	9	5
2890	76	14	6	4

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RESULTS AND DISCUSSION

The results generated from sample collection, description, preparation and analysis of the thirty ditch cuttings of Umuna well are as follows:

Lithologic Description

The samples consist essentially of shales with little band of sandstone at the base. At depths between (1010ft to 1620ft and 2060ft to 2780ft), the samples are highly fissile, grey in colour and showed no presence of carbonaceous material when treated with hydrochloric acid (HCL). The sample became carbonaceous at the middle between the intervals (1730ft – 1980ft). The interval between (2780ft to 2900ft), consists of coarse to medium grained sandstone (Fig. 2).

Particulate Organic Matter Components

The palynological slides generated from the samples prepared were analysed and yielded different particulate organic matters. The analysis involved studying the palynological slides under the transmitted light microscope to identify, count, and morphologically, describe the different particulate organic matter present. These particulate organic matters included palynomorph groups which are different species of pollen, spores, dinoflagellates, foraminifera test linings, fungal spores etc.; phytoclasts group which included opaque phytoclasts and non-opaque (translucent) phytoclasts; and the Amorphous organic matter groups which are reworked microbiological matter, resins from terrestrial high plants, microbial mats and bacterial extracellular polymeric substances. This analysis produced data presented in table 1. This statistical generated data was further analysed using StrataBugs application to generate Biostratigraphic charts (Figs. 3 & 4) for easy interpretations of the kerogen and palaeoenvironmental reconstruction of the well. Phytoclast was predominant in most of the samples analysed which is an indication of continental derived sediment supply, probably of marshland origin.

Palynological Result

The results (statistical data) of the palynological analysis of all the sampled depths analysed were further subjected to StrataBugs application to generate Biostratigraphic charts (Figs. 3 & 4). These charts included graphical display of the total particulate organic matter components generated in the statistical table (Table 1). The particulate organic matter components were standardised in percentages and plotted cumulatively to generate cumulative percentage distributions of the organic matter constituents with the total particulate organic matter components generated in the statistical table (Table 1). All other data were integrated into the interpretation chart for relative comparism of all the variables available for proper interpretation. Palynomorph occurrences in the samples analysed were sporadic with maximum occurrences at 1310ft and 2530ft. This high occurrence is an indication of nearness to continental source of sediment supply.

Ternary Diagram of the particulate organic matter.

Ternary diagram of particulate organic matter is a triangular plot of the three (Phytoclast, palynomorphs and amorphous organic matter) groups of the particulate organic matter. The palaeoenvironment of these palynofacies fields distinguished in ternary diagram has been generated and published by [11] which showed nine palaeoenvironments with their oxygen conditions for the different palynofacies fields distinguished in the ternary diagram. The standardised percentages of the groups of particulate organic matter was plotted in the ternary diagram (Fig. 5) as shown below.

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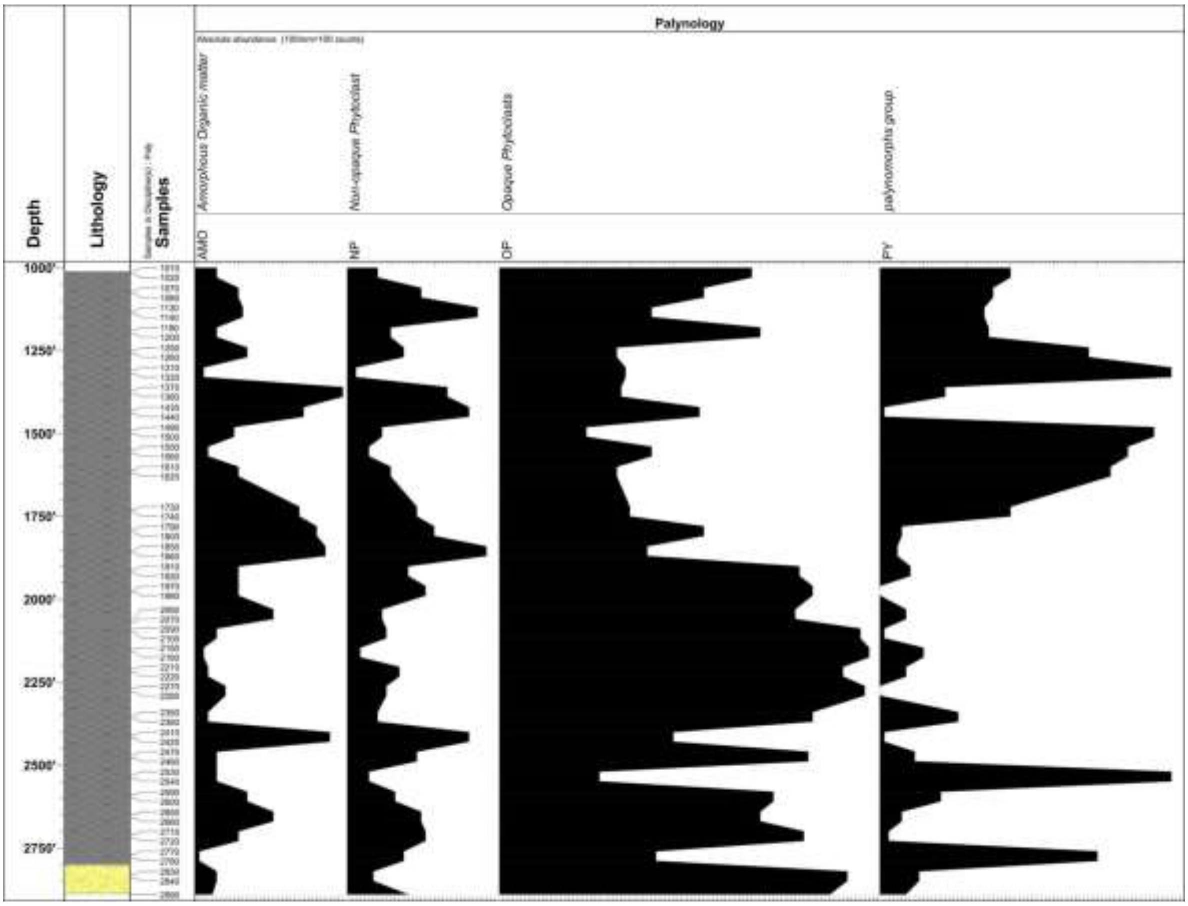

Fig. 3: Graphical display of the total particulate organic matter components in Umuna well.

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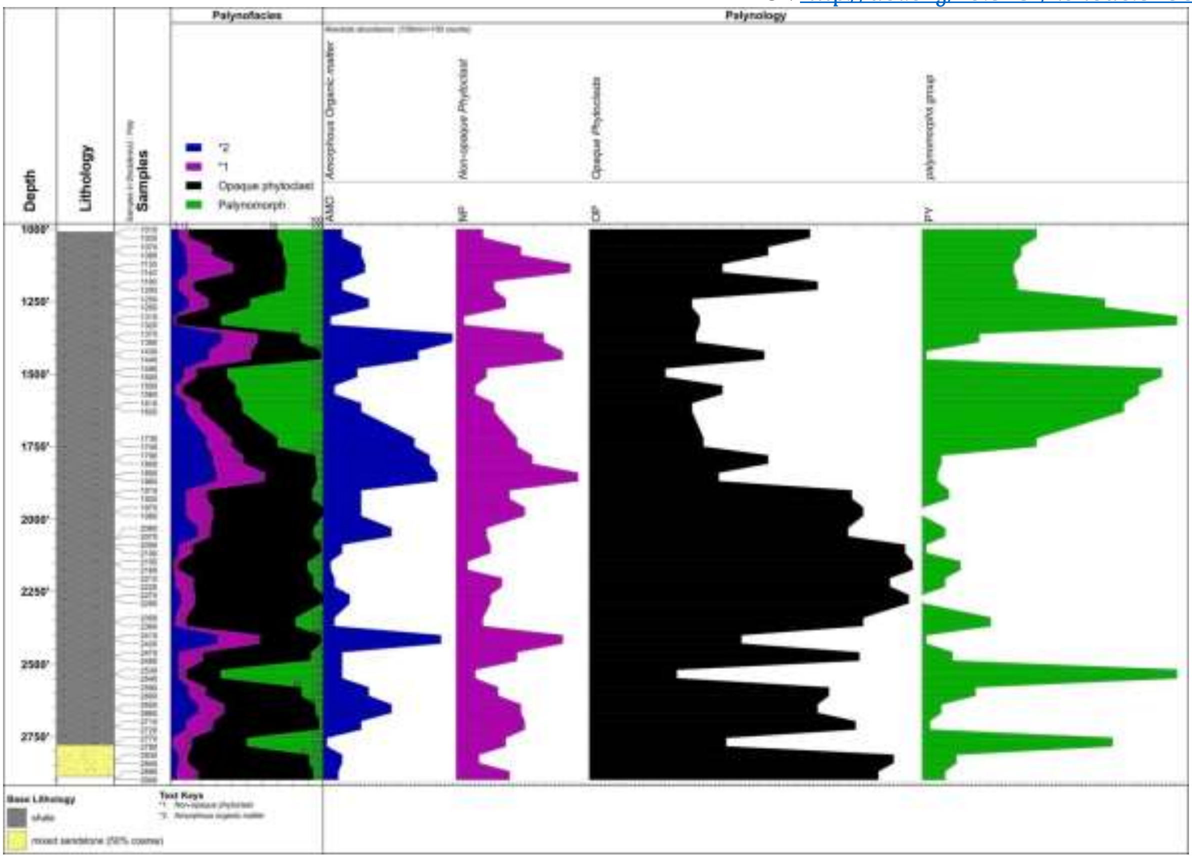

Fig. 4: Cumulative percentage distributions of the particulate organic matter constituents.

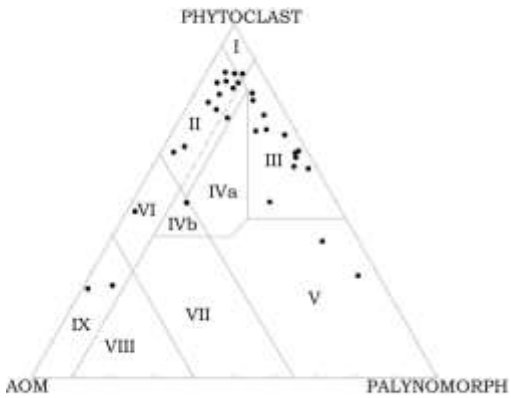

Fig. 5: Ternary diagram of the particulate organic matter components in Umuna well.

Discussion

Palaeoenvironmental interpretation of the ditch cuttings recovered from Umuna well was done based on the cumulative percentage distributions of the particulate organic matter (Fig. 4) and the data presented in the ternary diagram (Fig. 5). The palynofacies fields plotted from the particulate organic matter components corresponded to (I, II, III, IVb, V, VI and IX) of [9] palynofacies fields (Table 2).

Palynofacies field I: This field showed high phytoclast and very low amorphous organic matter and palynomorphs. It corresponded to highly proximal shelf.

Palynofacies field II: This field had amorphous organic matter watered down by high phytoclast contribution, nonetheless amorphous organic matter conservation was modest to good corresponding to marginal dysoxic-anoxic basin.

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Palynofacies field III: This field showed generally low amorphous organic matter preservation rate with moderate to high phytoclast abundance. Reworking and oxidation are mutual corresponding to heterolithic oxic shelf (proximal shelf)

Palynofacies field IVb: This palynofacies field has absolute phytoclast abundance. It showed the time of transition from shelf to basin resulting from progressive increased of rate of subsidence/water depth.

Palynofacies field V: This field showed low to moderate amorphous organic matter (degraded) and abundant palynomorphs. This corresponds to mud-dominated oxic shelf (distal shelf).

Palynofacies field VI: This field showed good amorphous organic matter conservation rate owing to the decreasing basin conditions. Complete phytoclast constituent was modest to high due to turbiditic input and/or general nearness to basin. This corresponds to proximal suboxic-anoxic shelf.

Palynofacies field IX: This field showed amorphous organic matter - controlled assemblages with minimal number of palynomorphs. This corresponds to proximal suboxic-anoxic basin.

Table 2: Showing palynofacies used for paleoenvironmental Interpretations (modified from [9]).

Depth	Palynofacies fields	Inferred palaeoenvironment	Comments
1010 - 1130	III	Heterolithic oxic shelf (proximal shelf)	Generally low AOM preservation rate; absolute phytoclast abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and reworking common.
1190	V	Mud-dominated oxic shelf (distal shelf)	Low to moderate AOM (usually degraded). Palynomorphs abundant. Light coloured bioturbated calcareous mudstones are typical.
1250 - 1310	III	Heterolithic oxic shelf (proximal shelf)	Generally low AOM preservation rate; absolute phytoclast abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and reworking common.
1370	IVB	Shelf to basin transition	Transition from shelf to basin in time (e.g., increased subsidence/water depth) or space (e.g., basin slope). Absolute phytoclast abundance depends on proximity to source and degree of deposition.
1430	IX	Proximal suboxic-anoxic basin	AOM-dominated assemblages. Low abundance of palynomorphs partly due to masking. Deep basin or stratified shelf sea deposits, especially sediment-starved basins.
1490 - 1730	III	Heterolithic oxic shelf (proximal shelf)	Generally low AOM preservation rate; absolute phytoclast abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and reworking common.
1790 - 1970	II	Marginal dysoxic-anoxic basin	AOM diluted by high phytoclast input, but AOM preservation moderate to good.
2060	III	Heterolithic oxic shelf (proximal shelf)	Generally low AOM preservation rate; absolute phytoclast abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and

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			reworking common.
2090 - 2210	II	Marginal dysoxic-anoxic basin	AOM diluted by high phytoclast input, but AOM preservation moderate to good.
2270	I	Highly proximal shelf or basin	High phytoclast supply dilutes all other components.
2350	II	Marginal dysoxic-anoxic basin	AOM diluted by high phytoclast input, but AOM preservation moderate to good.
2410	III	Heterolithic oxic shelf (proximal shelf)	Generally low AOM preservation rate; absolute phytoclast abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and reworking common.
2470	II	Marginal dysoxic-anoxic basin	AOM diluted by high phytoclast input, but AOM preservation moderate to good.
2530	IX	Proximal suboxic-anoxic basin	AOM-dominated assemblages. Low abundance of palynomorphs partly due to masking. Deep basin or stratified shelf sea deposits, especially sediment-starved basins.
2590	II	Marginal dysoxic-anoxic basin	AOM diluted by high phytoclast input, but AOM preservation moderate to good.
2650 - 2710	III	Heterolithic oxic shelf (proximal shelf)	Generally low AOM preservation rate; absolute phytoclast abundance dependent on actual proximity to fluvial-deltaic source. Oxidation and reworking common.
2770	VI	Proximal suboxic-anoxic shelf	Good AOM preservation rate due to reducing basin conditions. Absolute phytoclast content may be moderate to high due to turbiditic input and/or general proximity to source.
2830 - 2890	II	Marginal dysoxic-anoxic basin	AOM diluted by high phytoclast input, but AOM preservation moderate to good.

The palaeonenvironments of deposition penetrated by the analysed section of the ditch cuttings recovered from Umuna well ranged from marginal marine to shallow marine with varying oxygen conditions at the time of deposition. The changes in depositional environment bottom to top of the studied well represents the rhythmic interplay of fluvial activities on the delta alongside with sea level variations, accommodation space and rate of deposition with time resulting in deposition within the various depositional environments under varying oxygen conditions, ranging from littoral to middle neritic. From the palynofacies analysis, deposition of the studied sample started in the marginal marine at depths between 2890ft to 2830ft, the depositional environment changed to shallow marine at 2770ft and back to marginal marine at 2710ft. at 2530ft, shallow marine depositional environment sets in and changed again into the marginal marine depositional environment at 2470ft. the marginal marine depositional environment persisted until the deposition of 1430ft when the depositional environment changed into shallow marine and lasted briefly before changing into marginal marine at 1310ft to 1010ft. The various depositional environments are as shown using a schematic basin profile (Fig. 6). The typical morphology of these depositional environments is shown using a schematic block diagram (Fig. 7).

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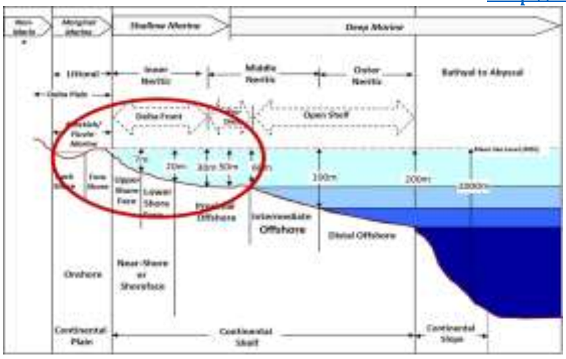

Fig. 6: Schematic Basin profile illustrating sections encountered in Umuna well.

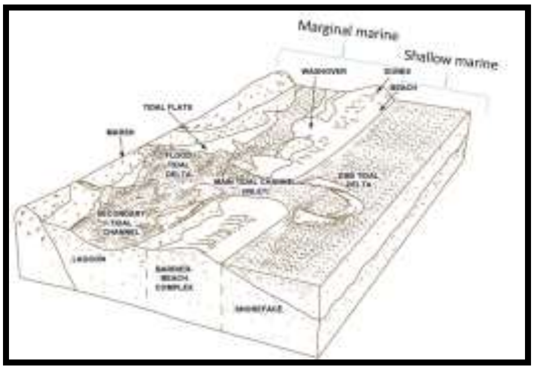

Fig. 7: Schematic block diagram of morphology of the depositional environments in Umuna well.

CONCLUSION

The activities of fluvial systems and variations in the sea level, accommodation space and rate of sediment influx affected the deposition of the samples of Umuna well analysed. The effect of the rate of burial and oxygen conditions were also indicated on the state and preservation of the particulate organic matter recovered from the samples prepared with predominantly, opaque phytoclast indicating the effect of burial and temperature.

The dominant palaeoenvironment of deposition encountered in Umuna well based of the palynofacies analysed, plotted on the ternary diagram and interpreted are between marginal marine to shallow marine, but predominantly marginal marine. The marginal marine depositional environments included, highly proximal shelf, marginal dysoxic-anoxic basin and heterolithic oxic shelf, while the shallow marine depositional environments included shelf to basin transition, mud-dominated oxic shelf, proximal suboxic-anoxic shelf and proximal suboxic-anoxic basin.

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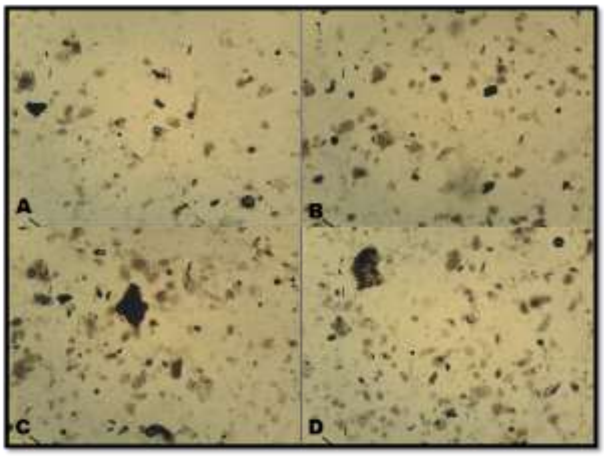
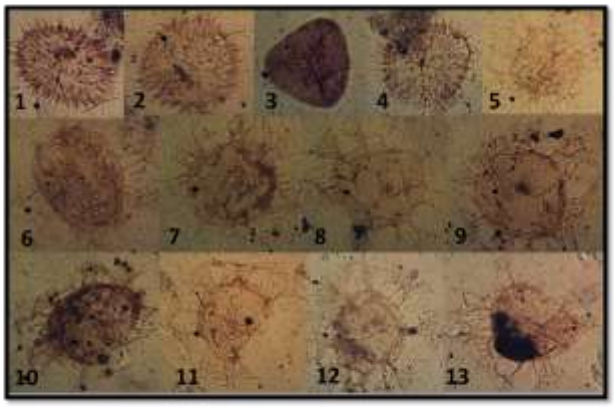
PLATES



Plates. A - D: Phytoclast and Amorphous organic matter; 1010ft; X 125.



Plates. 1 – 13: Palynomorphs; 1010ft; X 400.

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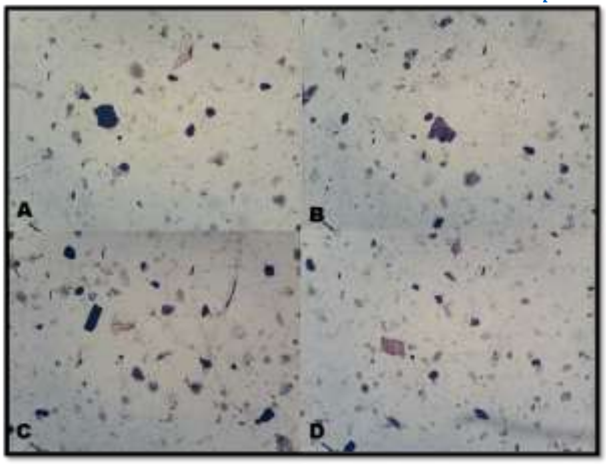
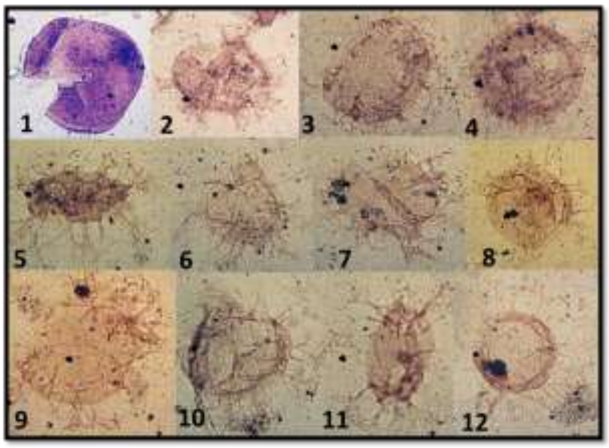


Plates. A - D: Phytoclast and Amorphous organic matter; 1070ft; X 125.



Plates. 1 – 12: Palynomorphs; 1070ft; X 400.